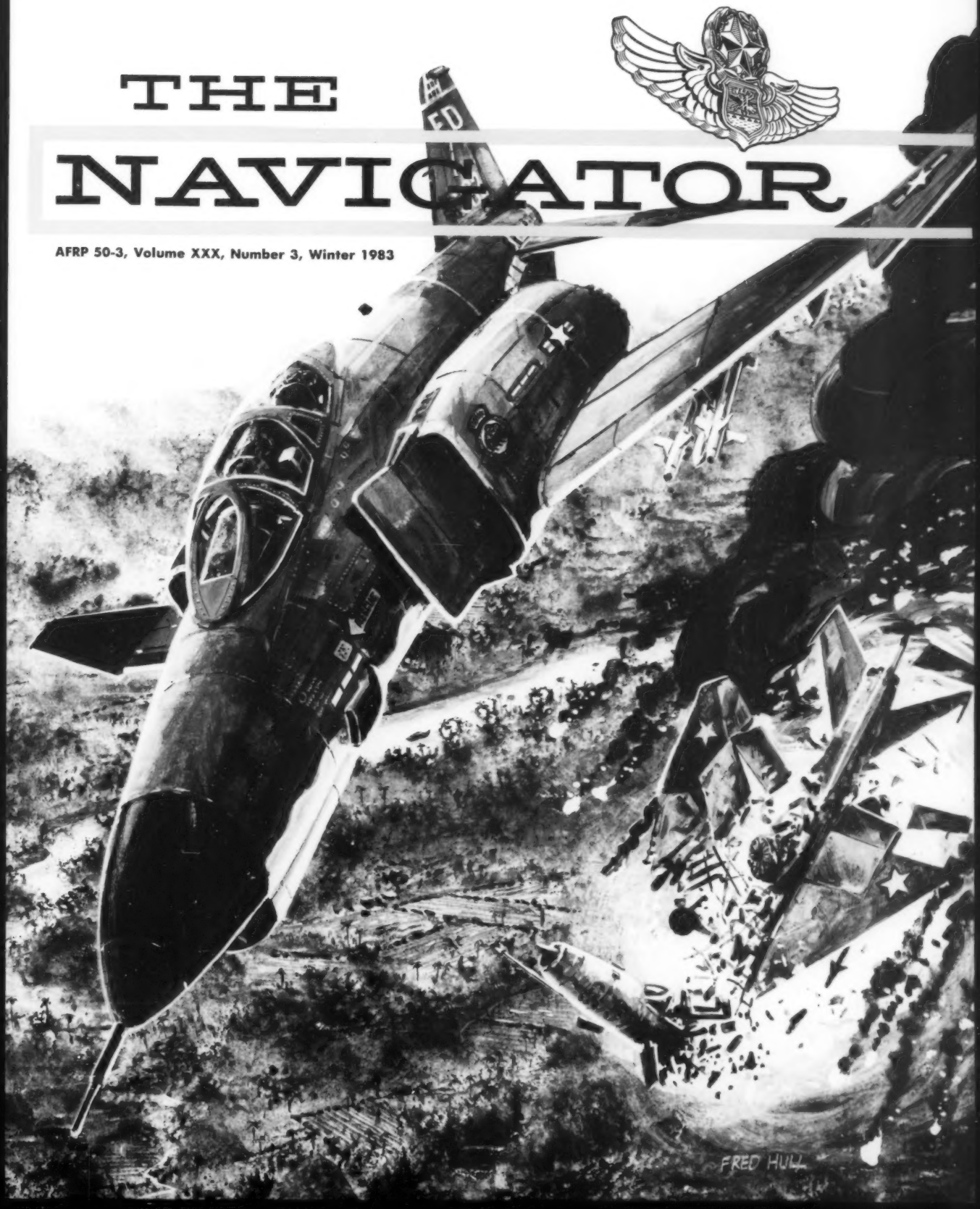
THE NAVIGATOR

AFRP 50-3, Volume XXX, Number 3, Winter 1983



NAV OF NOTE

COLONEL CALVIN R. JOHNSON

Colonel Calvin R. Johnson is the Director of Latin American Affairs and Chief of Staff of the U.S. Air Force Southern Air Division, Howard AFB, Panama. As Director, he oversees USAF relations with the air forces of more than 17 countries in Central and South America.

While Colonel Johnson is currently navigating Latin American affairs, he started out navigating B-47s at Dyess AFB, Texas, in May 1962, after completing undergraduate training at James Connally AFB, Texas, and upgrade training at Mather AFB, California. Since then he has flown in the EB-47E/L, the B-58A, EB-66 and C-130. A master navigator with 3,600 hours total flying time, the colonel has 558 combat flying hours and has logged 157 combat missions in Southeast Asia while assigned to Thakli and Korat Royal Thai AB in 1971.

A 1960 graduate of the U.S. Military Academy at West Point, Colonel Johnson has served as assistant professor of engineering at the U.S. Air Force Academy. In March 1976, he was assigned to the Tactical Air Command as a DC-130 navigator. He later became operations officer and squadron commander of the 22d Tactical Drone Squadron, Davis-Monthan AFB, Arizona. He completed his Davis-Monthan tour as the assistant deputy commander of operations, 432d Tactical Drone Group.

Following graduation from the Air War College in June 1980, the colonel moved to Mountain Home AFB, Idaho, to serve as deputy commander, 366th Combat Support Group. In July 1981, he was named commander of the 366th Combat Support Group, a

position he held until his selection as Director of Latin American Affairs/Chief of Staff, U.S. Air Force Southern Air Division, in September 1982. Colonel Johnson assumed his present duties in January 1983, following Spanish language qualification training through the Defense Language Institute.

About his present duties, Colonel Johnson explains, "This is an extremely exciting time to hold this job in Panama. Two challenges face us here. One is defense of the Panama Canal, working closely with our Panamanian counterparts with whom we share that task. The other is maintaining U.S. military influence in Central and South America through Air Force to Air Force contact."

"We work the challenge of Canal defense with a combination of Air Force Reserve, Air National Guard and active duty forces which exemplify our total force policy. The 24th Composite Wing at Howard, with its active duty crews and O-2A aircraft, maintains a permanent tactical air control system with a consistent level of local experience and expertise. That system is complemented by Air National Guard A-7s and crews who, on a rotating basis from the CONUS and Puerto Rico, provide close air support fire power for local training and contingency operations."

"This area is a real beehive when it comes to the number of commands and services involved. It's at the Air Division level that we pull it all together and make it work," says Colonel Johnson. "That's one of the things that makes this job so interesting. The military and political situation is unbelievably dynamic. Our primary job in the Latin American affairs area is to implement congressionally approved Air Force security assistance to the nations in the region. Since it is such a politically dynamic region, we must constantly reassess our long range security goals."

FROM THE EDITOR

If there was one prevalent criticism from our spring reader's survey, it was the question of THE NAVIGATOR magazine's service to the Weapon Systems Officer (WSO) community. Your charge, that much of our content benefits heavy airplane navigators, is valid. We should offer more to the fightergators—and we will, starting now.

I'm exceedingly proud of our lead article in this issue. What better practical knowledge can a WSO absorb than accounts of actual aerial combat? There is no teacher like experience. It therefore benefits all of us to hear and read about the experiences of those who fought in combat—especially those who prevailed. It was my distinct pleasure to interview one such party—Lieutenant Colonel Charles B. DeBellevue.

Colonel DeBellevue was the second USAF flier to qualify as a Vietnam ace. Commissioned through ROTC in 1968, he entered Undergraduate Navigator Training in September of that same year. Following his initial assignment as an F-4 WSO with the 335th Tactical Fighter Squadron, Seymour Johnson AFB, NC, he transferred to Thailand, in October 1971, to fly combat with the 555th Tactical Fighter Squadron (the "Triple Nickle"). It was during his year of service with the "Triple Nickle," that then Captain DeBellevue downed four MiG-21s and two MiG-19s, qualifying him not only as an air ace, but as the leading ace of the Vietnam conflict.

The air war in Southeast Asia produced just five aces; of them, three were navigators. The very first ace was Navy Lieutenant Randy Cunningham, who, along with his F-4 backseater, Lieutenant William Driscoll, is credited with five MiG kills. The first USAF ace was Captain Steve Ritchie, who scored kill number five on 28 August 1972. Following him were Air Force Captains DeBellevue and Jeffrey Feinstein (both F-4 WSOs) who tallied their kills in September and October 1972, respectively.

The story of Vietnam's air war, and the men who fought in the Asian sky, makes excellent professional reading. If you want to learn more about the subject, I heartily recommend a book titled *Aces and Aerial Victories: The United States Air Force in Southeast Asia, 1965-1973.* Published by the Office of Air Force History, the volume should be available at your base library. I hope that our interview with Colonel DeBellevue might stir your interest in air warfare history. Our past holds the clues to our future.

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Department of the Air Force

THE NAVIGATOR

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On 8 July 1972, then Capt Charles "Chuck" DeBellevue sat behind Capt Steve Ritchie, in an F-4E, as they flew MIGCAP support for a SEA Linebacker airstrike. Just west of Phu Tho and south of Yên Bai, North Vietnam, they engaged two MiG-21s in an aerial dual. After only about one-and-a-half minutes of combat action, Ritchie and DeBellevue had downed both "bandits." The two aerial victories moved each man closer to the eventual title of fighter "Ace." Our cover depicts the historic air battle. For more about Vietnam's leading ace, read the exclusive interview with Lt Col DeBellevue, starting on the next page.

AFRP 50-3

Distribution: One copy per four navigators.

In May, Lieutenant Colonel Charles B. DeBellevue visited Mather AFB to address personnel of the 455th Flying Training Squadron. During that visit, the editor interviewed Colonel DeBellevue who, as an F-4 weapon systems officer, scored six MiG kills in Southeast Asia, making him the leading ace of the Vietnam conflict.

NAVIGATOR ACE-

An Interview with Lt Col Chuck De Bellevue

THE NAVIGATOR: In reviewing accounts of your combat engagements, I noted that the 8 Jul 72 dogfight seemed extremely dramatic and exciting. You downed two MiG-21s. Which kills were those?

COLONEL DEBELLEVUE: That was a flight of two—my second and third kills. Yes, they were exciting. We were the egress CAP, the rear guard for the strike that day. Our orbit point was about 70 miles west of Hanoi. Two aircraft in the Hanoi area, an F-4 and an F-105, had engine fires and egressed from the area. Hearing their radio calls, we thought it would be a good idea to head east. As we turned, our radar controllers started calling blue bandits, MiG-21s arcing around Hanoi from the east. Suddenly, the controllers told us that we were merged. For two minutes no one saw the MiGs. Then, at eleven o'clock and just to the left of the nose, I spotted a black flyspeck against a white cloud. We turned to meet him head on. A few seconds later we were line, abreast with a MiG-21 going in the opposite direction. Ninety seconds and three AIM-7s later, after a hard turning fight, two MiG-21s were destroyed. Those kills were exciting because the distances involved were close, the speeds were fast—a lot of Gs—and quick decisions were required to get the job done. Looking back, every engagement was exciting—my adrenalin was always way up. In a crisis situation, like air combat, you do well or you fail—there's no in-between. You come out first or you don't go home. The adrenalin is so high that it's really hard to measure the level of excitement. When you're in there doing your thing, everything is habit patterns and memory—checklists. There's no extraneous talking going on—it's all very short and to the point. The job is to get the other guy and then get out. You can't afford to hang around. We never went anywhere straight and level—we always kept the airplane moving. The worst place to have an enemy aircraft is behind you because that's where you can't see him. Smoke trails always were a big problem. Our engines put out a lot of smoke. All an enemy had to do was find a smoke trail, follow it, and we were at the end of it. If we didn't move the airplane around and check our six o'clock, we might have been a fireball.

Lt Cmdr Duke Cunningham was the first SEA Navy ace in the F-4. He said that it is one of the most honest airplanes in the world. How do you react to that statement?

Well, not having flown anything but an F-4, and, of course, the various models each handle

a little differently, I'd say the F-4 is very honest. It talks to you. If you're doing something it doesn't want to do, it will let you know. Now, you can press the issue and keep going with it—in which case the airplane will pretty much take over—go out of control or whatever. But before you lose control, it will talk to you. The wings will start rocking or, in the D model, which is what we flew in SEA, once you reach a regime approaching the limits of maximum performance, you can't see the instrument panel because the airplane is vibrating and shuddering so much. It's talking to you. If you know how to fly it, you'll ease off

The AIM-9 will turn inside a dime and give change.

a little bit—no big deal. It's when you don't listen to the airplane that you get into trouble. The newer models have leading edge slats to smooth things out—those birds don't tell you quite as much but they will still talk to you. It's how well you interpret these inputs that determines how well you fly the airplane. Some guys pick up on that real quick and some don't. I've always been fond of the F-4. It's an honest airplane.

To follow up on that—you were credited with two MiG-19 kills. I've read that the F-4 is much more controllable in combat than the MiG-19. Did you observe that to be the case?

We were told that the MiG-19 was a very hard airplane to fight because we couldn't outturn it. Supposedly, only an F-86 with maneuvering slats and an afterburner could outturn the MiG-19. I was flying an F-4D—not anything close to that. The MiG-19s were good. In fact, we were told that North Vietnam's better pilots flew them. On one of my engagements, we were heading out and had to run through two MiG-19s. We chose to fight them because there was no way to simply shoot through. They would have turned and run us down. We would have run out of gas trying to turn away from them, so we had to neutralize that threat. One fact saved us—we saw them first. We had 90 degrees of turn on them when they saw us. We knew they had spotted us because they jettisoned their wing tanks to get down to fighting weight. We were already clean, having gotten rid of our tanks prior to an earlier fight. We ended up behind them—not where they wanted us to be. We were armed with AIM-9 sidewinders (heat seekers)—very deadly missiles. The AIM-9 will turn inside a dime and give change. We fired two at the trailer and he left the flight burning. We fired another at the lead guy. That missile impacted the afterburner. The pilot had a chance to bail out. However, he continued on for a few seconds, straight and level, and then rolled inverted and impacted the ground. In recording my six MiG kills, two of them were single kills and two were double.

How many of your kills were with Steve Ritchie?

Four were with Ritchie—the MiG-21s. The two MiG-19s were with John Madden who scored three kills while in Southeast Asia.

From your limited experience in the F-15, can you draw any comparisons between it and the F-4?

Well, the F-4 is a big airplane. It hauls a lot, carries a lot of missiles and has a gun on the E model. It has a lot of capability. The F-15 is built by the same company. It hauls basically the same munitions—four AIM-7s, four AIM-9s and a gun. It is also a big airplane. It gets the job done. Now, if you take the airplane out of the picture, you must consider the men flying it—operating that system. When I go up against another airplane I'm not going up against just the airplane or just the crew. I'm going up against the entire system. It is how well I fly my airplane against how well an enemy flies his airplane that counts. The other guy can be a better flyer in a better weapon system but it's how well I do against him on that particular day. Of course, I always want to be in tiptop shape to get the job done. Second place can be fatal. By knowing the enemy's airplane and capability, you may be able to change your tactics to put him at a disadvantage.

I read that aerial tactics are strictly a game of relative motion and time and distance problems. Do you agree with that statement?

Aerial combat is a very fluid situation. I have to get my airplane a certain distance from the enemy's and within certain parameters if I'm going to employ an AIM-9 or AIM-7. Meeting the parameters involves time and distance. If I don't project his flight path or if I fail to position my airplane relative to his path, when I'm ready to fire, I may not be able to take a shot. The game is constant motion. You must

continuously project yourself ahead. What's that guy going to do now? What is his best shot? What is my best shot? Where is he headed? I must maneuver my airplane to gain position by anticipating his action. If he counters my move, then I must change tactics. The guy who can do that best wins. It boils down to action and reaction.

Fighter guys constantly talk about "energy." What does that mean and how does it relate to aerial combat?

The concept of aircraft energy is very important. We're concerned with two types of energy—kinetic and potential. If I'm down low, I want to have a lot of kinetic energy—I want to be fast. An F-4—or any airplane—turns best at a specific speed based on its weight and the shape of its airfoil. There is a certain airspeed—we call it corner velocity. If you're at that speed you can make your quickest, tightest turn. That's kinetic energy—airspeed. If I'm high, by virtue of that fact, I have a lot of potential energy which I can convert to airspeed. In the F-4, we use the vertical factor a lot. Fast down low allows the F-4 to zoom in the vertical. As the airspeed decreases, by putting

...given a choice between being good and being lucky, I'd probably rather be lucky.

the aircraft on its back and using the force of gravity—God's G—to help, a very tight turn can be made. Going downhill, I accelerate better. Energy management dictates how well you may do in air combat. When low and slow, I've got to use brute force to regain airspeed. The F-4 is a brute force airplane but it accelerates even better going downhill. We did a lot of fighting against the MiG-21, a very sleek airplane. It could accelerate down low a lot better than we could and it could maneuver slower—it had that slight advantage on us. How one manages energy can greatly influence the outcome of a combat engagement.

In THUD RIDGE, Col Broughton mentions superstitious habits that take root during combat duty—as a flyer approaches number 100, the magic mission—such habits as not changing your flight suit or your underwear, or gloves, or other things like that. You logged 220 combat missions. What superstitious habits did you practice?

The magic 100th mission didn't apply to us as it did with guys who flew in Rolling Thunder, the strikes into Route Pack VI during the 67-68 timeframe. They needed 100 missions to go home. We had no such quota. Many of us logged more than 100 missions in the north. I flew 96—several guys flew 150. We weren't in the same situation as Col Broughton, but the superstitions were still there. A new pair of gloves can't fly an airplane. I needed an old set. Or, to break in a new set, I had to fly a very low demanding mission so that the gloves would learn. We did everything in the same way. The helmet stayed the same—I didn't change anything. My present squadron, the 335 TFS, was one of the original RAF Eagle squadrons in WWII. In our squadron building, we have pictures of some of the aces from the original squadron. One photo shows a young pilot sitting in his airplane holding a teddy bear. I imagine he wouldn't have flown that day without that teddy bear. In SEA, some guys flew with lucky charms. I didn't have any, per se, but I wore the same outfit every day—I tried to follow the same routine.

Did you follow some special practice prior to a mission, such as eating certain food, or putting your left boot on before the right?

No, nothing like that, but we did go through a procedure that got us ready for each mission. Everybody was scared but it wasn't the type of fear that impairs your performance. It probably helps. I hated flying with new guys. Often, returning to PAC 6 with a veteran was safer than a training mission with a new guy. (The northern part of Vietnam was divided into two sections. PAC 6 BRAVO was an area from east of Hanoi to the west. The Air Force worked that area. The Navy worked their strikes in

For a new guy to get ready, he must think, "Hey, I'm the best WSO in the world. I'm the guy that's going to get the job done."

PAC 6 ALPHA which was the area around Haiphong harbor.) I think everyone was a little superstitious. A friend of mine was shot down during our last mission. He was picked up right away. Upon his return to the base, the guy took a stuffed alligator he had been carrying for good luck and burned it—the luck had run out. You might say that if you know what you're doing, you don't need superstitions or

luck. Well, maybe so, but given a choice between being good and being lucky, I'd probably rather be lucky. A combination of both is best. While in SEA, we were visited by a man from the Air University who was writing an article on the superstitions of fighter jocks. He interviewed us and specifically one flier who had collected idols and symbols from every conceivable religion. This guy always went into combat chanting a jingle he made up, just in case he got shot down. He planned to say, 'Hey look, I've got one. I'm one of you.'

If I were a young WSO scheduled to go into aerial combat tomorrow morning, what would be the most important thing you could tell me about going out to do a job I've never done before?

First, you must know yourself. Second, you must know your weapon system—especially in a demanding mission like patrol of PAC 6. Whether your job is to drop bombs or fight air-to-air, the eve of your first combat mission is not the time to learn. If you haven't studied prior to the night before, then it's too late to polish your act. You should know exactly what's going on. If you're the lead backseater, it's your job to navigate into the area. As a WSO, you're not just a copilot, navigator, or bombardier; you're all of them. You do many things. We flew four hour air-to-air missions. During each of them, we had at least one air refueling into the target area—maybe one coming back—and we also had about 20 minutes on station. The backseater was as responsible for the success of each mission as the frontseater. We felt we could do anything the pilots could do. Pilots trained their

During combat engagements...you're constantly doing what it takes. You end up with a neck that is a couple of sizes larger.

backseaters because they knew so much depended upon them—they had to know what was going on. For a new guy to get ready, he must think, "Hey, I'm the best WSO in the world. I'm the guy that's going to get the job done." I knew my weapon system cold. Everything, from the radar down, was committed to memory. A lot of self preparation was required. During the big missions up north, much of our preparation was getting 'up' for the flight, because there was a good chance that you might not come home. That didn't play in one of my missions; I wouldn't let it, but I was ready. My roommate got shot down during one of our missions. That's really eye-watering. Flying combat in a fighter is not quite like fighting in the infantry where you live with it and are in the same foxhole, shoulder-to-shoulder, for days at a time. After combat, at Udorn, we could at least get a chance to relax until the next day's mission. But then your buddy goes down and it makes you stop and think. It brings reality right up to your nose.

How stressful is the combat environment?

You are under a great deal of stress. During combat engagements we didn't feel any Gs. The adrenalin was so high that we hardly felt anything. You're constantly doing what it takes. You end up with a neck that is a couple of sizes larger. If you need to look at the radarscope, while you're pulling six Gs, you look at the radarscope. If it's time to look behind you, then you do that. You have to stay loose. If you don't, you can pull a muscle. But you adjust to that stressful environment. The first time you go out on a six-hour combat mission, you come back whipped. Eventually you get used to it. You're still tired, but it's not as bad. In fact, when you score a kill, the adrenalin is pumping so much that two days later you still haven't landed—it's a natural high. Some guys drank heavily in SEA. I used to have a bar bill that ran over $100 per month from buying drinks for the bar when I got a kill. Since drinks were only 25 cents, that's considerable. However, no one could afford to fly without everything going for him. It took 110% to get the job done.

Well, let's change the scenery and bring you out of the combat environment and back to Mather. You graduated from navigator training in 1969. Now you're seeing Mather training in 1983. How do you view the changes you've seen?

When I went through navigator training most instructors had little fighter experience. I had no idea of what fighters would involve. In that respect, training today is much better. The program now gives students a chance to understand what is happening at a slower pace than the F-4 travels. At 200 mph in a T-37, things are easier to manage than at 420 or 480 in an F-4. The Tweet lets students start out

slow, and then speed up. RTU was also different back then. For intercepts, we probably had a better training program than today's students do—ours was more specialized. When I went through RTU, we had six weeks of radar training. It was just navigator instructors out of ADC—F-101 navs teaching us how to run intercepts, operate the radar, and things like that. We didn't fly initially. Six weeks after our arrival the pilots arrived and we started the flying portion. In those days, pilots flew as backseaters. I was in one of the first classes of navigator backseaters. Most of the frontseaters in the RTU classes were backseat pilots moving up to the front seat. The academic program was not highly structured—instructions came mostly from the guy you crewed with. He would teach you his techniques. I think today's student is much better prepared to go into fighters when he leaves Mather. Of course, the first experience in the F-4 is a terrific learning situation too. A new backseater starts off expecting someone to look over his shoulder and say "yea" or "nay." Very shortly he's going to find out that there's no such thing in the fighter business. He's on his own. He'll go with an IP for a couple of rides, probably be assigned to a more experienced AC in the squadron, but soon he'll be with one of the newer aircraft commanders. All of a sudden, he must know what is going on. It is up to him.

As a backseater, if I flew with a new AC, I had to know the front seat as well as the back seat, since our airplanes were often strangely configured due to battle-damage repairs.

That leads me to the inevitable question. In 1982, you were reassigned to the 335th at Seymour Johnson as a lieutenant colonel pilot. You returned to that squadron that you originally joined as a first lieutenant WSO in 1970. Would you comment on the two different experiences?

Of course, the 12 years between assignments have made a big difference. When I came out of RTU, as a navigator assigned to the 335th, I knew the airplane and the job, but I was still searching. My confidence level was not very high. I could work everything, but I was unsure of my ability. The experience that followed taught me what flying fighters is all about. We flew the airplane and got the job done. When I returned to the 335th as a lieutenant colonel, it was the same squadron—moved to a new building—and I found that the people are just as conscientious about flying and making sure the job gets done. I think we do more now—at least from what I remember. It seems that the unit is tasked with more and the personnel are required to do more. I'm very impressed with the job we do.

Having been a WSO and fought in combat, do you feel any unusual affinity toward WSOs that perhaps other pilots don't share?

I can tell right off whether or not a WSO is doing his job. Before I left the backseat, I had done virtually everything an F-4 could do. In combat, I participated in bombing raids, air-to-air fights, forward air-controller missions—everything. As a backseater, if I flew with a new AC, I had to know the front seat as well as the back seat, since our airplanes were often strangely configured due to battle-damage repairs. It helped if a WSO could talk his frontseater around the cockpit, if needed. When I switched to the front seat, one advantage was knowing the back. After being in the front seat a while, I could go up with a young backseater and say, "OK, here's what you're going to do." On an intercept ride, for instance, the radar not only sweeps right and left, but the tilt can be adjusted up and down. It depends on where you aim the radar as to when you see the target. If the backseater can't see the target, he may start adjusting the radar tilt faster than necessary. I would often see the target before he did. With my experience, I can talk to a rookie WSO and help him out. On the other hand, I'm probably also extra critical because I know what can be done in the rear seat. When I was a backseater, I never thought of myself as a second-class citizen. Any job is what you make of it. We are all part of the same team. As you know, there are many navigator jokes and pilot jokes. I've heard the best and worst of both. As a pilot, I don't treat fliers differently. I judge others not by their wings, but what they demonstrate to me.

Is there any reluctance from WSOs to fly with you because of your unique experience and extra-critical nature?

I don't think so. They may be reluctant to fly with me at first because they're not sure of where I'm coming from. My reputation as an

ace preceeds me everywhere I go. Guys are usually in awe of that. However, I think I'm pretty down to earth. I tend not to let what's happened get in the way of things. People can fall back on their laurels only so much. It's nice to face an audience and talk about history and tell war stories—we all enjoy that. But there is a job to do. I'm not ready to be put out to pasture—I still want to do my share.

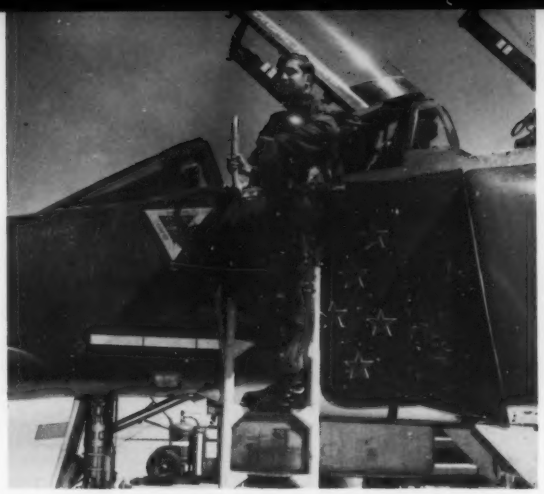
What attributes are necessary to be a good WSO?

Know your airplane—that means studying the books. If you don't know your job cold, you're wasting someone's time as well as your own. Know yourself. That will become particularly important in combat. What are your limits? Not everyone has the same limits. Some pilots and WSOs can fly the airplane with their eyes closed while others have to work at it. There is no room in the airplane for a passenger—you are part of the crew. If the airplane misses a target, whose fault is it? Well, it is 50% the backseater and 50% the frontseater. It is not just one fellow's fault, but the crew's fault. In 1972, the Navy conducted a test to determine the best experience combination for a front and backseat team. They combined a highly qualified frontseater with a highly qualified backseater—an excellent crew. A mediocre frontseater with a top-notch backseater made a better crew than an outstanding frontseater with an average backseater, according to the Navy's test. I have found their results to be true. A good WSO must also be directive—he must be assertive. In my opinion, the pilot probably should be a shade more aggressive than the backseater, if for no other reason than his requirement to occasionally say, "Hey, have you checked this yet?" You really can't compare the crew concept in the F-4 with that in the bomber, or tanker, or transport. The fighter has two fellows tasked with a very demanding job—not a static condition but one that is constantly changing.

Sometimes a situation reverts to eyeball against eyeball. That's when the twoseater can really pay off.

What do you see as the future of the two-seat fighter?

A two-seater offers several advantages. It is easier to get the job done with a two-place



airplane. There are two people to concentrate on the mission. I would like to see another two-seat airplane come down, and I think there will be one. Two people offer much broader capability in a wider variety of missions. You don't need two seats in every situation, but two seats offer a definite advantage in certain cases. An extra set of eyeballs always comes in handy. The frontseater can't look everywhere. Once in a while our "magic" radar malfunctions. Sometimes a situation reverts to eyeball against eyeball. That's when the two-seater can really pay off.

The World War II-Korea American Fighter Aces book contains a photo of a 1967 American Fighter Aces Convention. Since you are a fighter ace, have you ever been invited to one of those conventions?

I attended one right after Southeast Asia, in San Antonio, in 1972. The group is becoming rather small.

Who keeps the official records on the score for awarding the title of aerial combat ace?

The title is awarded after five kills. Once you shoot down an airplane, you submit a claim which has to be substantiated. In my case, the rest of the flight was able to substantiate most of the kills. Official Air Force orders are then issued awarding you a kill. The same procedure applies for the Navy and other military branches.

Do you have any final comments for our readers?

Flying a fighter is quite different from flying other types of airplanes. The sum total of all your efforts is to be ready to go to war. Not that you ever will, but if you are ever called upon to

defend your country, you must be ready. Whether you are a backseater or a frontseater, readiness is essential. You never know when the call will come. It may be a phone call in the middle of the night. There is little time to prepare after that. You must be up to speed all of the time. In war, you either finish first or you lose. It is up to you to make sure that you come in first. Patton summed it up when he said, "Dying for your country will not win a war." Our constant readiness is our strongest deterrent against war. We're not a war-mongering country. We prefer to let others live as they choose. But, no one should tell us how to live. This country was created by people seeking freedom—who were willing to risk their lives to preserve that freedom. That commitment is our heritage. It is up to us to preserve that heritage for our children and their children. We must strive not to cause war but to prevent it.

Thank you for sharing your views and experiences with us.

THE NAVIGATOR thanks Capt Peter Deibig, 455 FTS, Mather AFB CA, for his assistance with this interview.

Professional Recognition

CAPTAIN FREDERIC G. WILSON

Since we published Captain Wilson's firsthand account of his 8 April 1982 bird strike incident, ("Phantoms and Feathers," THE NAVIGATOR, Winter '82) and reported his receipt of TAC's "Aircrew of Distinction Award" and the Air Force Association's "Earl T. Ricks Memorial Trophy," he has gone on to garner even more recognition.

Captain Wilson and Captain Gregory A. Englebreit, both of the 190th Tactical Reconnaissance Squadron, Idaho Air National Guard, won the 1982 Cheney Award for their safe recovery and landing of an RF-4C, after the aircraft was severely damaged from impact with a whistling swan. The impact and resulting damage to the plane's canopy left the pilot, Captain Englebreit, severely injured and semiconscious. Consequently, Captain Wilson, the weapon systems officer, had little choice but to land the RF-4C from the rear seat—no mean task in itself for a pilot, but an even greater challenge for a navigator.

Despite severe visibility limitations, Captain Wilson flew an excellent formation approach to a safe landing. For his courageous efforts to save his fellow crew member and the aircraft, Captain Wilson not only earned the '82 Cheney Award but also the Kolligian Trophy. Named in honor of First Lieutenant Koren Kolligian, Jr., the trophy is presented for outstanding feats of airmanship by an individual aircrew member in averting an aircraft accident or minimizing its seriousness. Lieutenant Kolligian was declared missing in a T-33 off the coast of California in 1955.

The Cheney Award is named for Lieutenant William H. Cheney who was killed in an air collision over Foggia, Italy, in 1918. It is presented annually by the Air Force Chief of Staff for an act of valor, extreme fortitude, or self-sacrifice performed in connection with an aircraft.

For a dramatic recounting of Captain Wilson's heroic efforts on 8 April '82, read "Fango - 45 Calling Mayday" in the October 1983 issue of the *Reader's Digest*. As an interesting aside to this story, we can report that nearly one year to the day after this first bird strike incident, Captain Wilson was crewing an RF-4C, with Major David R. Hudlet, when a bird strike shattered the right quarter of the windscreen. This time, the pilot was not seriously injured and landed the aircraft himself.

Captain Fred Wilson, far right, and Captain Greg Englebreit receive the 1982 Cheney Award from General Charles Gabriel, center, USAF Chief of Staff.

Adventures of a

Mr Walt DROWNS
Lear Siegler, Inc.
Mather AFB, CA

"Big Shaky," "The Aluminum Overcast," "The Douglas Racer"—just a few of the names given to the Douglas C-124 Globemaster by the men who flew it all over the world with MATS and, later, MAC. The C-124 and I first met at Travis AFB in late 1962 when I was assigned to the 1501st Air Transport Wing.

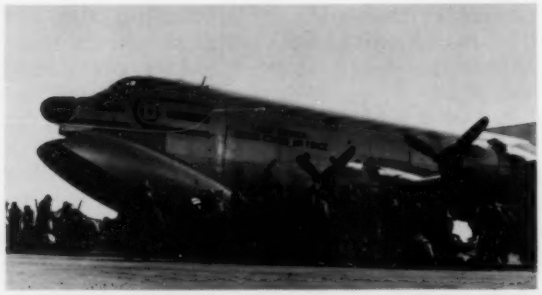
I arrived at Travis with shiny gold bars, flashy silver wings, and big dreams of being a "jet navigator." Those dreams were quickly dashed when I learned that the C-135B squadron I was supposed to be assigned to was fully manned. Consequently, I had been reassigned to the 85th Air Transport Squadron, one of two C-124 squadrons on the base. Was I disappointed? How about shocked? The only time I'd ever seen a C-124, I thought it must have won the ugly airplane contest.

My first look at the navigator's "office" in the C-124 didn't do much to raise my morale or expectations. I was destined to work with such modern equipment as an astrocompass, an APN-9 Loran, a hand-held sextant, and a driftmeter located downstairs in the cargo compartment. The voices of my navigation school instructors echoed in my ears, "We're only mentioning this equipment for general interest—you'll never see it in the field." Well, here it was in all its antiquated glory. Surely they didn't expect me to navigate across an ocean with equipment older than I. I was soon assured by my first C-124 instructor, a grizzled first lieutenant with several hundred hours under his belt, that "It's a piece of cake. You'll get the hang of it in no time."

Then came the big day; my first trip as a MATS crew member. The flight plan was completed and reviewed, the mission briefed, and we were finally on our way to the airplane. At last, I was going to be a "real world" navigator. On the ride to the aircraft I asked the flight engineer why they called the C-124 "Big Shaky." He replied, "You know you're airborne when you stop shaking up and down and start shaking side to side." What I thought was a great joke turned out to be a paradigm of truth.

Finally, the big moment arrived—we were cleared for takeoff. We charged down the runway with engines roaring, equipment rattling, and the entire airplane trying to shake itself to pieces. After what seemed an eternity, we lifted off and began climbing to 10,000 feet. We seldom flew much higher, as "Big Shaky" wasn't pressurized. We leveled off at cruise altitude, set the IAS at a sizzling 175 knots (don't laugh, that's 210 True), and turned to our flight-plan heading for Honolulu. I called the pilot for a TACAN bearing and DME, since he was the only one with a TACAN, and plotted them for my departure fix. That was the last time I was absolutely sure of our exact position until we reached Honolulu.

Shakygator



After the fix, my first priority was a heading check. As MATS instructors liked to say, "An accurate ETA isn't much good if you're not flying toward your destination." Out came the astrocompass. Between hints from my instructor and glimpses into AFM 51-40, Vol III, I managed to install it in the astrodome and complete a celestial heading check. (If you're under 30, you probably think the astrodome is a Houston sports stadium.) The N-1 compass and astrocompass differed by one degree. I favored putting the correction on the astrocompass but my instructor wouldn't allow it.

I decided my first en route fix would be an evening planet LOP crossed with a Loran line. After several erasures and deleted expletives, my precomp was complete. I stepped up into the dome, quickly located the planet, and completed my shot. Hmm, nothing too complicated about using a hand-held sextant. I was slightly behind by this time, so I decided to get my Loran line late and adjust it to fix time. By the time I sorted out and aligned all of the pulses, the fun had just begun. With the old APN-9, you had to count the 1,000 ms markers, then go to the next function and count the 500, 100, and 10 ms markers. Next, you added all the values and threw in an extra 100 ms for calibration error. Finally, I managed to plot the fix, compute a wind, and complete a position report.

Since only rich people in new airplanes had Doppler in those days, we computed all of our winds from fix to fix. After spinning each wind, we drew it on the weather chart and compared it with the forecast wind flow. This was our basis for a proposed wind. After several winds were drawn on the chart, we could predict the movements of pressure systems and forecast en route winds quite accurately.

As the night wore on, things became more complicated. When I climbed back into the astrodome for my first three-star fix, I immediately regretted all of those hot Texas days

I had spent napping in the air conditioned comfort of the planetarium. Carl Sagan is fond of saying that there are billions and billions of stars in the heavens. I was desperately searching for only the three I needed. In addition to my problems locating stars, the Loran started receiving sky wave trains. After staring at the CRT, I despaired that there had to be at least a 26-hop Z sky wave in there someplace. Thanks to the patience and skill of my instructor, we sorted out enough information to accurately position the aircraft and prop up my severely sagging confidence.

Finally, we reached Honolulu. My long night was over, but I felt like an old veteran then, with an ocean crossing in my log book and faith that the basics really do work. "Big Shaky" and I had crossed the Pacific together and we would do so many more times before we parted ways. By then I would have acquired a firm grasp on the fundamental concepts of navigation and I would hold the self confidence to go anywhere in the world using them.

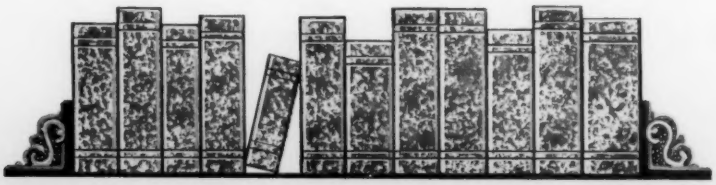
Later assignments led me to increasingly higher performance aircraft and more complex and demanding missions. But the basics remained the same. I would rely upon lessons learned in the C-124 many times when the sophisticated modern navigation systems held their breath and died. The matter always boiled down to how fast, in which direction, and for how long. If you simply remember that, you can't go too far wrong. Take it from an old "Shakygator."

Mr Drowns obtained his degree through Operation Bootstrap and was commissioned in 1961. After UNT at James Connally AFB, he was assigned to the C-124 and C-130E at Travis AFB. Following duty in the RB-57F/C at Kirtland AFB in 1971, he served a SEA tour. Next came duty at Mather AFB prior to retirement. Mr Drowns now serves as a supervisor in the T45 simulator at Mather AFB.

Professional Reading

Captain Donald W. RIGHTMYER
391 TFS/DO
Mt Home AFB, ID

Professional reading is receiving renewed emphasis lately thanks to the sharpened focus on our profession of arms through the lens of Project Warrior. Most of us have heard or read something in ROTC, SOS, or Air Command and Staff courses about the benefits of a consistent and continuing professional reading program. Many of us want to pursue a reading program, but often we don't make the time. Hopefully, with Project Warrior and an increased understanding of the challenges facing us, Air Force navigators can cultivate a renewed interest in reading about and studying our past.



This is not just a pitch for Project Warrior, but a renewed opportunity to reassess your professional reading and review some of the newly published works that relate to the 'Warrior' mission. A basic reference for selecting professional books is the *Air University Suggested Professional Reading Guide.* Published annually, the guide lists 20-30 books with a short description of each. To get a copy, just write to the Air University, Maxwell AFB, Alabama 36112.

The real meat of any professional reading program includes books offering the most comprehensive coverage of selected subjects. The Office of Air Force History, in Washington, D.C., has published several books on various aspects of our Air Force heritage. During the last decade, one of their largest efforts has been documenting the USAF role in the Southeast Asia conflict. A multi-volume series, entitled *The United States Air Force in Southeast Asia,* is being produced with volumes already in print on Operation Ranch Hand, search and rescue, and air base defense.

The first blue hardback work in the Vietnam series is *The Advisory Years To 1965* by R. Frank Futrell. Mr. Futrell is a well-known writer of Air Force history with two previous classics: *Ideas, Concepts, Doctrine* and *The United States Air Force in Korea, 1950-1953. The Advisory Years* covers the beginning of U.S. Air Force involvement in Southeast Asia, from the days of the Truman administration through the Gulf of Tonkin Resolution and the escalation of U.S. military involvement in 1965. The essence of the USAF role, throughout that 15-year period, was essentially advisory. Increasing participation in combat operations developed as the years passed.

One of the most interesting programs during the early 1960s was called Farm Gate. This was the name for USAF counterinsurgency forces trained at Eglin AFB under the direction of then Chief of Staff Curtis LeMay. Initially equipped with T-28s, SC-47s and B-26s, the Farm Gate detachment went to Vietnam in 1961 to officially train Vietnamese aircrews.

The remainder of this book provides a broad view of Air Force involvement in the developing command and control system, largely under the Army's direction, in South Vietnam. The Air Force's 2d Advanced Echelon (ADVON) formalized intratheatre air control and, years later, became the more familiar Seventh Air Force. This volume opens the way for succeeding titles on the in-country air war (South Vietnam); the war over Laos and the Ho Chi Minh Trail; Rolling Thunder, in North Vietnam; and Air Force efforts in civic action.

The most recent release from the Office of Air Force history is specifically designed to support Project Warrior. *Air Superiority in World War II and Korea* is the historical recollections of four former Air Force generals who played vital roles in the fight for air supremacy during those two wars. Generals James Ferguson, Robert M. Lee, William W. Momyer and Elwood R. "Pete" Quesada gathered in 1982 to recall such experiences as the campaigns over North Africa and western Europe, air power during the Normandy invasion, the air battle in Korea and the effect of Ultra intelligence on conduct of that battle. This paperback is an excellent small volume on air superiority. Hopefully more books like this will follow.

The selections I've discussed are just a few to add to your professional reading program. I'll highlight additional titles in future issues of THE NAVIGATOR. In the meantime, keep reading and fly safe.

Capt Rightmyer graduated from the USAF Academy in 1973 with a degree in History. After UNT and F-4 RTU at Homestead, he flew F-4s in Korea, England, and West Germany. Next came assignment to the HQ USAF Office of History. Capt Rightmyer now serves at Mt Home AFB.

Navstar GPS

past, present, and future

Lieutenant Colonel John F. SCHEERER
Major Joseph GASSMANN

Space Division/YEE
Los Angeles AFS, CA

Editor's Note: Since this article was written, another Block I GPS spacecraft has been launched, bringing the number of orbiting Navstar satellites to seven.

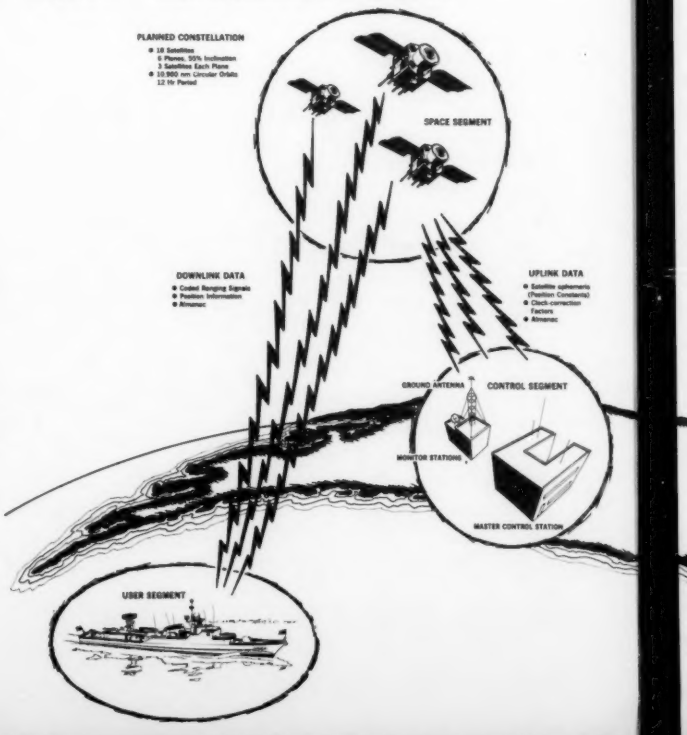
Numerous articles have been written about the Navstar Global Positioning System (GPS) program and how it works. This article highlights the development of GPS space, control, and user segments as well as a sampling of program test results and future plans. GPS not only provides navigational information but also worldwide NUDET (nuclear detonation) detection capability with the advent of Block II satellites. Navstar offers three-dimensional positioning accuracy to within 15 meters spherical error probable (SEP), velocity data to .1 meter per sec, one sigma RMS, and timing as close as 100 nanoseconds as related to universal time.

A Joint Program Office (JPO) manages the Navstar GPS program. JPO members include representatives from all branches of the military, Department of Transportation, Defense Mapping Agency (DMA), NATO and Australia. The three major segments (space, control, and user) represent large research and development investments (Fig 1). The space segment involves the largest number of satellites of any space program (an 18 satellite constellation plus 3 active spares) and the largest satellite control network outside the Air Force Satellite Control Facility. The GPS user segment includes the largest avionics program within the DoD.

In addition to navigation program management, the JPO oversees the NUDET detection program. NUDET will aid verification of the Limited Nuclear Test Ban Treaty by monitoring near-surface and altitude detonations. The NUDET package includes numerous detonation sensors which are totally integrated into the Block II Navstar satellites. With the inclusion of NUDET, the GPS program has grown to four major programs under one umbrella.

Navstar's chief benefit to navigation is its provision of a common coordinate and timing

Figure 1 **Major segments of the GPS system**

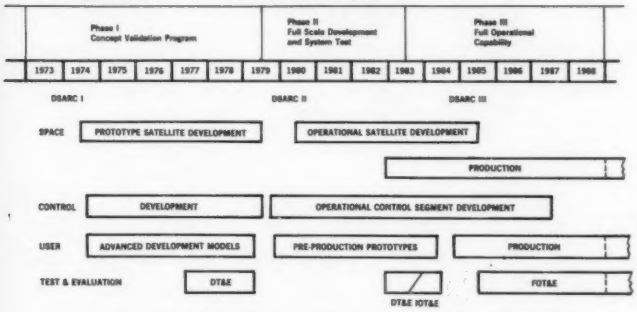


system for any receiver in air and space or on land and sea. In a relative mode, the position and timing relationships become 3-5 meters SEP and 3-5 nanoseconds.

SPACE SEGMENT

Six Block I or research and development satellites already have been launched into 63° inclination orbits at 10,900 nm using Atlas F boosters. In 1981, a seventh launch was unsuccessful. Of the six orbiting satellites, four are operating beyond expectations using the primary atomic standard. One is usable only with a backup clock (a crystal oscillator versus an atomic standard). The navigation package on the remaining satellite is unusable. GPS spacecraft employ both rubidium and cesium atomic frequency standards. Four additional Block I satellites have been built and will be launched as needed (Fig 2). (These four have been modified to accommodate the NUDET detection sensors.) All future satellites launched will feature a NUDET detection capability.

Figure 2 **GPS program schedule**



Presently, the Block II operational satellite is being built. Called "Navstar 12," this prototype is a design qualification satellite not intended for deployment. Design and production of the Block II spacecraft began in 1980 (Fig 2). Rockwell International and the USAF Space Division negotiated a fixed price contract for 28 satellites—an historic plan because it is a multi-year funded program. Of the 28 satellites, seven will be produced and launched annually until 21 spacecraft are in orbit (18 plus 3 spares.) These 21 satellites will provide 98% probability for 18 continuously active satellites. Remaining production satellites will serve as replacements. The life-design goal of each spacecraft is 7.5 years with a mean mission duration of 6 years. These satellites will be launched from the Space Shuttle, into 55° inclination, 10,900 nm orbits. When deployed, the 18 satellites will permit continuous, worldwide, three-dimensional position and velocity determination. Each satellite will

Figure 3
Navstar satellite

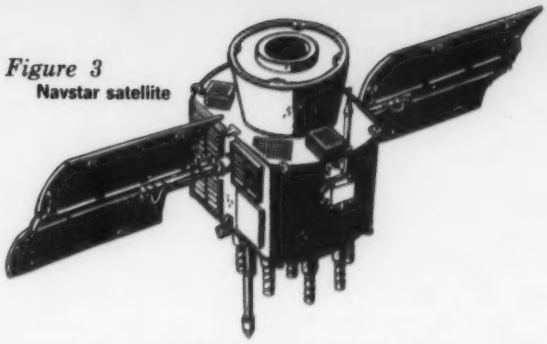
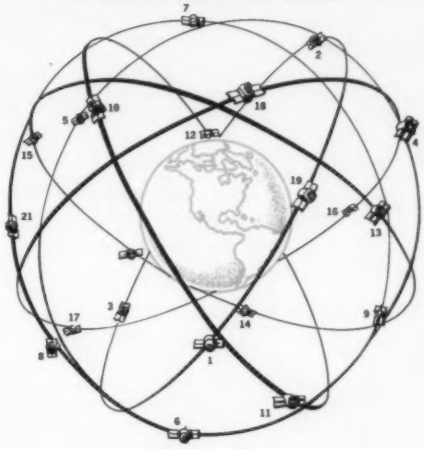


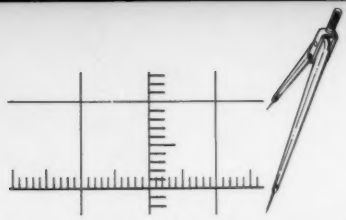
Figure 4 **Navstar GPS/NDS 6 plane configuration—18 satellites plus 3 active spares**



transmit a pseudorandom noise navigation signal at L1 (1575 Mhz) and L2 (1227 Mhz). NUDET detection information will be transmitted on L3 (1381 Mhz). A potential user must receive signals from four satellites within a favorable geometric pattern to solve the three-dimensional positioning problem. Four to seven satellites normally should be "visible" to any user (Fig 4).

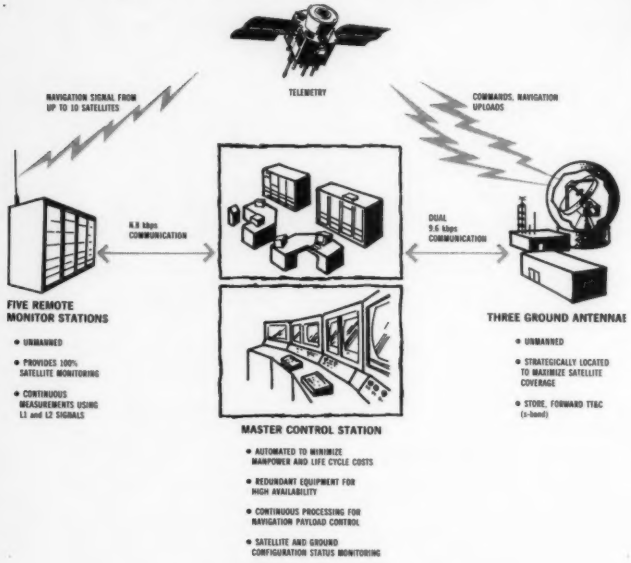
CONTROL SEGMENT

The GPS master control and upload station is at Vandenberg AFB. Other monitor stations are located in California, Hawaii, Guam and Alaska. The Vandenberg station uploads the navigation data message into each satellite. Monitor stations track each satellite and provide information to generate succeeding navigation data messages. Presently, the GPS control segment is being phase-upgraded from the initial control segment to the operational control segment. Already, the computer at Vandenberg AFB has been upgraded to a single-thread operational IBM 3033 computer. Some software also has been upgraded. In Jan 83, the system's navigation data message format was revised to its fully operational mode.



The final operational master control station, consisting of two IBM 3033s (Fig 5), will be collocated with the Consolidated Space Operations Center at Peterson Field, Colorado. The navigation data message will be uploaded three times per day. To support the upload, three station ground antennas will be installed with one each at Diego Garcia, Ascension Island and Kwajalein. Five monitor stations will be positioned with one each in Hawaii, Colorado Springs, and the remainder collocated with each of the upload stations. The implementation schedule is shown in Fig 2. IBM is the control segment contractor.

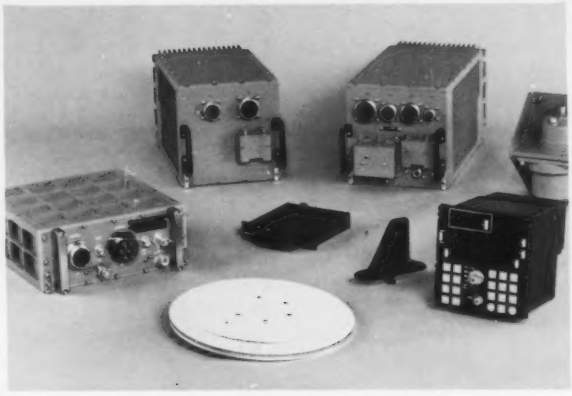
Figure 5 **GPS operational control system**


NAVIGATION SIGNAL FROM UP TO 10 SATELLITES
TELEMETRY
COMMANDS, NAVIGATION UPLOADS
4.8 kbps COMMUNICATION
DUAL 9.6 kbps COMMUNICATION
FIVE REMOTE MONITOR STATIONS
• UNMANNED
• PROVIDES 100% SATELLITE MONITORING
• CONTINUOUS MEASUREMENTS USING L1 and L2 SIGNALS
MASTER CONTROL STATION
• AUTOMATED TO MINIMIZE MANPOWER AND LIFE CYCLE COSTS
• REDUNDANT EQUIPMENT FOR HIGH AVAILABILITY
• CONTINUOUS PROCESSING FOR NAVIGATION PAYLOAD CONTROL
• SATELLITE AND GROUND CONFIGURATION STATUS MONITORING
THREE GROUND ANTENNAE
• UNMANNED
• STRATEGICALLY LOCATED TO MAXIMIZE SATELLITE COVERAGE
• STORE, FORWARD TT&C (s-band)

USER SEGMENT

During the Navstar concept validation phase, Texas Instruments and Magnovox Corp built and tested 44 advanced development model user sets which have been in constant use ever since. During the present full scale development phase, Rockwell-Collins and Magnavox are developing competing equipment for the operational system. Each contractor is building a family of 54 low, medium, and high dynamic user sets (one, two and five channel receivers). In 1984, a Defense Systems Acquisitions Review Council (DSARC) will award the equipment production contract. (see Fig 2 for detailed schedule).

GPS avionics components



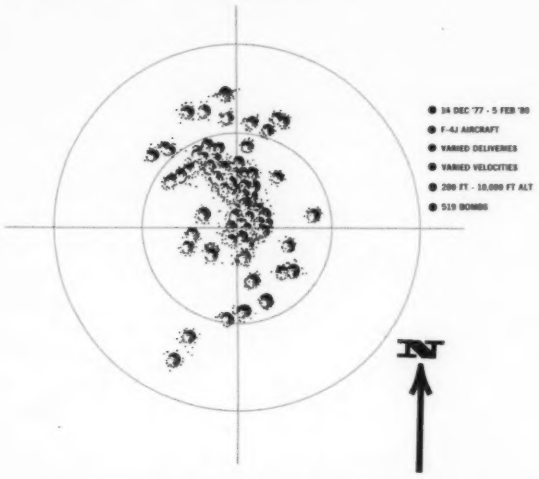
GPS manpack receiver

TESTING

In March 1977, the Navstar test program began collecting data to verify 22 field test objectives. These range from navigation accuracies to rendezvous application, ILS-type landing approaches, precision weapon delivery, jamming resistance, and environmental effects on satellite and navigation signals. This data aided in preparing for DSARC II in 1979. Five satellites, four monitor stations, a master control station and an inverted test range were deployed and tested. The 44 ADM user sets, ranging from manpacks and low-cost receivers to high dynamic and high anti-jam receivers, were tested on foot soldiers, aboard army ground vehicles, naval vessels, and on UH-1, P-3, C-141 and F-4J aircraft. Over 800 missions tested navigation, data survey, time transfer, passive rendezvous, precision landing approaches, cargo drops, and over 600 "blind" (coordinate) bomb drops. The test results have repeatedly verified the first advertised Navstar navigation/positioning accuracy of approximately 10 meters SEP. Delivery of MK-82 bombs, from straight/level approaches and toss (LADD) maneuvers, yielded dramatic results approaching the guided

munitions accuracy arena (Fig 6). Besides testing for DSARC II, additional follow-on testing was conducted. Navstar use during various defense exercises, such as RIMPAC, Solid Shield, FLEETEX, HELBAT, and NATO demonstrations, produced comparable results. Along with the defense industry, other user groups have successfully built and tested GPS receivers. For instance, DMA has placed a GPS receiver, called GPSPAC, on a NASA satellite (LANDAT-D), launched in July 1982. So far, GPSPAC has performed well and provided about 10 meter SEP real-time positioning information. LANDSAT-D is in a 400 nm circular orbit.

Figure 6 **GPS bombing results**



Navstar performs exceedingly well when used with other types of positioning equipment. Many people incorrectly assume that Navstar will replace standard inertial measurement units (IMUs). Contrarily, the synergistic effects of both systems have proven fantastic. For instance, Navstar permits highly accurate in-flight IMU alignment. Thus, it can be used to keep an IMU precisely updated. The IMU, in turn, provides the short-term aircraft attitude and dynamics data required for improved Navstar tracking. With both systems supporting each other, the end product is drastically improved by an increased force-multiplier effect.

FUTURE PLANS

Most space vehicles have benefited from belated guidance to enhance their survivability; Navstar is no exception. Plans are underway to replace the present S-band tracking telemetry and commanding (TT&C) system with an EHF and L-band TT&C system. This improved telemetry and command package will enhance Navstar's anti-jam protection. As previously stated, the Block II spacecraft already have a crosslink to support the NUDET detection mission. Analysis shows that this feature can be used to support a concept called crosslink ranging. With the ability to range between satellites, the current major errors in track ephemeris and clock terms can be significantly reduced. Such reduction will increase user accuracy to 10 meter SEP, versus the present 15 meter SEP, with a baseline of three uploads per day per satellite. Or, a 15 meter SEP can be maintained with just one upload per day versus three. This accuracy can be achieved using only one monitor station tracking one satellite for one hour per month instead of the present baseline requirement of five monitor stations for virtual continuous tracking of all satellites. For the control segment, we are developing a concept which employs a small high-volume computer to interface with any MILSTAR (communication satellite) EHF terminal, regardless of the platform. This will offer the major advantage of aligning control elements with war-fighting elements. Such alignment will permit Navstar to survive through all conceivable war scenarios.

Navstar means many different things to many different people. To everyone, it offers accurate, reliable data to help us do our jobs better. This space system holds promise to improve our military capability well into the future with its applications limited only by our imagination.

Lt Col Scheerer earned a master's degree in Electrical Engineering from AFIT and an MS in Business Administration from the University of Utah. He has served with the Air Force Security Service, the Foreign Technology Division at 7 AF HQ, Vietnam, and the Air Force Satellite Control Facility. Presently, Lt Col Scheerer is the Director of Systems Engineering for the Navstar GPS.

A graduate of St Louis University, Maj Gassmann earned a master's degree in Aerospace Engineering from the University of Arizona. After UNT and EWOT, he had operational tours in the B-52 and F-4, as well as a SEA tour. Maj Gassmann served in Development Plans at the Space Division before his assignment to the Navstar JPO in System Engineering.

RADIO NAVIGATION—

from RDF *to* VOR

Mr Frank Kingston SMITH
Ocean City, NJ

To the layman, the term "navigation" often elicits an image of someone wielding a spyglass or sextant. Although thousands of airplanes shuttle between communities in the United States every day, few nonflyers have any idea how airplanes navigate from one place to another, whether an airline jet or a small private aircraft. One simply turns on a radio, twists a knob to tune into an appropriate frequency, and then rotates other controls to determine the exact course to fly. Modern airborne equipment links with ground-based stations to provide a visual indication of the airplane's position, groundspeed, and progress throughout the flight. It was not always so.

Aerial navigation once meant picking one's way over the terrain from one clearly identified landmark to another. Perhaps the first example of planned point-to-point flight was in July 1909 when Louis Bleriot crossed the English Channel in a monoplane of his own design. It took 36½ minutes for the 25 hp engine to carry him on that 38 km (23½ mi) trip. Bleriot took off from Calais and kept his eyes riveted on the white cliffs of Dover, which loomed on the rim of the western horizon. That was short-range visual navigation; Bleriot's airplane had no compass.

In 1911, only eight years after the Wright brothers' first flight at Kitty Hawk, Lincoln Beachey, then one of the Curtiss exhibition pilots, flew a rickety, box kite-like biplane from New York to Philadelphia, covering the 145 km (90 mi) in 2 hr 22 min, to demonstrate the airplane's transportation value. Because he sat in the open, he could not use a chart—nor did he have a compass. His navigation aid was intercity railroad right-of-ways, which were soon known to all aviators as the "iron compass." Within months, the pilot of a Wright Model Ex made an even more dramatic flight. Calbraith P. Rodgers flew across the United States in a winding course, following railroad tracks all the way. He was followed by a supply and support train, so the epic flight had to follow abutting railway trackage.

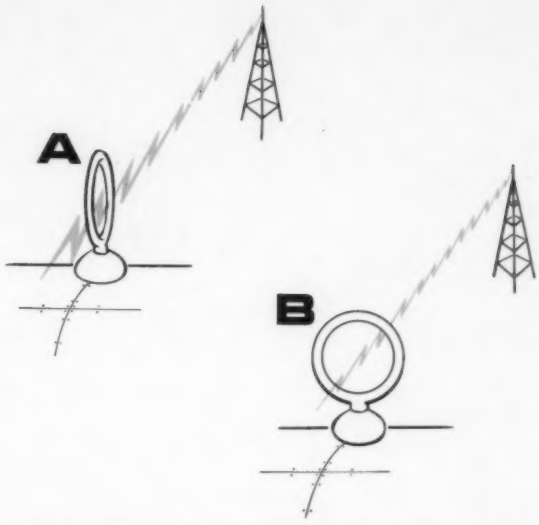
Known as "pilotage," this cross-country navigation is still practiced today in good weather. Using modern aeronautical charts, the pilot/navigator flies by constantly comparing details on the chart with landmarks on the ground. Many lightplane, recreational pilots still use pilotage, skimming along at altitudes below 914 m (3,000 ft) following rivers, power lines, railroads, and the "concrete compass"—the highly visible interstate highway system.

After World War I, pilots of open cockpit airplanes with a magnetic compass began using a new form of direct point-to-point cross-country navigation—"dead reckoning," a corruption of the word "deduced." Dead reckoning was first used by sailors operating out of the sight of land. Their premise was that if one knows the ship's—or airplane's—position or point of departure, a line can be drawn on a chart, to the destination, and the distance measured. Knowing the ship's speed and holding the charted compass course, the navigator can predict how long it will take to transit the distance. Upon departure, the time is noted and added to the estimated time en route to figure an estimated time of arrival. When the latter comes up on the clock or chronometer, the navigator can reason that the ship is near the destination and can begin to scan for landmarks (a landfall) to complete the trip visually.

In practice, many factors must be considered for reliable dead reckoning. A cross current will move the ship—or aircraft—off to the side of the baseline course, proceeding against a current will lengthen the time en route, or going with the

current will shorten it. Intrinsic problems, called "deviation," occur with every magnetic compass installation. Dislocation of the magnetic North Pole, from the geographical North Pole, creates "magnetic variation." On a ship moving at relatively slow speeds, dead reckoning is leisurely when compared with a 161 km/hr (100 mph)—or faster—airplane. But it is a valid form of aerial navigation. Charles A. Lindbergh dead reckoned his way for 33 hours from New York to Paris and, a few months later, for 27 hours from Washington, DC, to Mexico City. Most of both flights took place in bad weather at night. During World War II, navigators used dead reckoning to lead aircraft fleets for hundreds of kilometers across hostile territory, because all ground-based radio stations were shut down as a precaution against enemy use.

Radio navigation was introduced in the late 1920s, primarily for the then-new passenger airlines flying 161 km/hr (100 mph) Fokker, Stinson, and Ford Trimotor aircraft. Pilots of those early airliners often flew in poor visual conditions, picking their way across the countryside by combining pilotage and dead reckoning, just as the barnstormers and early, open-cockpit airmail pilots had done. However, development of instrumentation for flying in clouds was on the horizon. With instruments, airline pilots could climb through an overcast, fly "on top" to their dead-reckoned destination, then descend through the undercast, hoping that, when they broke out, something would look familiar and they could complete the flight by old-fashioned pilotage. The thought of flying on airways in clouds, without an air traffic controller, makes modern pilots shudder at the in-flight collision hazard, but few airplanes were flying in those days.



The rotatable RDF loop antenna produced the strongest signal when the loop was parallel (A) to the radio emission. Reception was weakest when the loop and the transmitter signal were at right angles (B). For navigation, the weakest aural signal provided the most accurate line of position.

In the mid-1930s, radio technology had advanced significantly—receivers were reduced in size and complexity, and special aircraft radio equipment had been created. The airborne receiver weighed 34 kg (75 lb) and took the space of two large suitcases, so that only big airplanes could carry it, but it immediately changed navigation. The first giant step was the rotatable, direction-finding loop antenna.

The aerial radio direction finder (RDF) was another device adapted from ship navigation. By changing audible radio signal volume while rotating the loop antenna, with the radio tuned

The rotatable, direction-finding loop antenna is easily seen on this North American O-47

Photo courtesy of the California State Military Reserve

into a ground-based, low frequency station, a pilot/navigator could establish a line of position (LOP) or determine bearings from the transmitting station to the aircraft in flight. However, the RDF system had a serious ambiguity problem: the navigator did not know immediately whether he was tracking toward or away from the transmitter. Without making turns and course changes to obtain additional LOPs, one could overfly the ground station and not know it. Nevertheless, the crude and clumsy loop antenna was in airline and military use until the late 1940s, when it was supplanted by the automatic direction finder (ADF). An ADF dial, with a center-pivoted needle mounted on the instrument panel, provided immediate directional information. When the radio was tuned in to the nondirectional radio beacon (NDB), the needle would swing and point directly at the station. The ADF is still widely used today, not only to receive the FAA's NDB system but also to monitor commercial, low frequency broadcast stations for news or music while navigating in good weather.

During the late 1930s, as faster airplanes such as the Boeing 247-D and the DC-3 came into use, the non-directional ADF was not precise enough to define the new system of aerial "highways" known as civil airways. To provide the requisite accuracy, radio engineers created a new, low frequency radio range system. The heart of this airways system was a horizontal antenna that emitted a signal, in the shape of a figure 8, perpendicular to the antenna wire, or aerial. By siting two crossing antennas, the edges of the dual figure 8 signals could be overlapped. Then, if one antenna emitted the Morse Code letter "A" (dit-daah) and the other emitted the letter "N" (daah-dit), the area of overlap would transmit both signals, which merged into a steady hum, heard over the pilot's headphones. This aural signal was called a radio beam, and a pilot flying on-course was said to be "on the beam." By locating a series of aural ranges along the airways, with the beams pointing at each other, radio beams led airplanes over charted routes.

For the first time, pilots could fly on schedule when the weather was too poor for visual flight or pilotage. Not only could pilots climb and descend through clouds, but they could fly through them continuously, staying on airways by riding the invisible beam. Furthermore, they were now able to use the ground-based radios for instrument landing approaches. The pilots made timed (procedure) turns until they could descend low enough to see the ground and land visually.

In actual operation, however, low frequency amplitude modulation (AM) radios had a serious shortcoming: meteorological interference—static. Aeronautical navigation and communication transmissions, like radio programs on commercial low frequency AM stations, are disrupted by thunderstorm activity, which creates crashing static and makes the ADF needle whirl wildly as it points at every lightning strike within range. When pilots most needed radio navigation aids for instrument flight—especially landing approaches—thunderstorms either masked or completely obliterated the radio signals. Eventually, that problem, too, was solved by electronic wizardry.

Early in World War II, a top secret discovery was the use of previously unavailable parts of the radio spectrum in the very high frequency (VHF) and ultra high frequency (UHF) bands. Electronics experts discovered the unique property of both VHF and UHF—radio reception was not affected by thunderstorm activity. A pilot could communicate without static interference, even when surrounded by lightning. Furthermore, frequencies could be selected by using crystals in both transmitters and receivers. The only shortcoming was that, unlike the long-range, ground hugging signals of low frequency ground stations, VHF/UHF radio signals travel in direct "line-of-sight" from the ground station to the aircraft. At 152 m (500 ft) of altitude, VHF/UHF range is only 48 km (30 mi), but it increases as the aircraft climbs. An aircraft at 4,572 m (15,000 ft) can receive a signal from 253 km (157 mi) away.

Another World War II top secret was that VHF/UHF radio signals were used for special navigation services. Army pilots operating from and returning to fixed bases could dead reckon both the outbound and homebound courses, but naval aviators had a special problem. They launched from aircraft carriers that could move 60 or 70 nm in any direction from the launching point. Low on fuel and physically tired, pilots faced the serious dilemma of finding their carriers after a three or four-hour sortie.

Electronics specialists developed a device that was mounted on carriers to radiate 360 separate VHF/UHF radio beams, one for each degree of the magnetic compass and always aligned with magnetic north. When within line-of-sight range, detectors in returning aircraft could select and isolate any one of those 360 radiated beams or "radials." On the instrument panel, the detectors indicated the magnetic course toward the ship

and the distance to the carrier deck in nautical miles, whether the airplane was flying toward or away from the ship along that radial.

When the war ended, this equipment evolved into the cornerstone of our modern airways system. The military retained the UHF part of the radio spectrum and the VHF segment was allocated to civil aviation. Within a few years, the old four-leg, low frequency, aural radio range airways structure was replaced almost entirely by the new technology spawned by war.

Because the ground-based stations on which the system was constructed operated in the VHF spectrum and were omnidirectional (covering 360° rather than having only four legs), they were called VHF Omnidirectional Radio Ranges, or VORs. Many pilots referred to them simply as "omniranges," or "omnis." The lines connecting the stations—the new civil airways—were called "Victor" (the phonetic alphabet letter for "V") and numbered on charts as V-1, V-2, etc. Today, hundreds of Victor airways crisscross the United States, forming an invisible latticework of electronic guidance available to all aviators.

Now, precise cross-country navigation is possible for all pilots and navigators, professional and private. Modern aviation electronics are so miniaturized that dual installations of navigation and communications radios are commonplace in small private airplanes. Weighing only a pound or two and taking no more space than a couple of cartons of cigarettes, they have 720 crystal-controlled communication frequencies and 200 navigation frequencies. Many small airplanes, and virtually all of the larger ones, are autopilot equipped with "couplers" that hook onto a VOR radial and fly precisely along its centerline, automatically compensating for crosswinds by setting up a crab angle. Autopilots can also fly instrument approaches to special VHF landing system equipped airports.

The VOR system made small private airplane travel a practical reality and promoted enormous growth in personal flying for business and pleasure. As technology moves ahead, in giant strides, new and better air navigation systems still evolve, but those flying and navigating in United States airspace can rely upon the VOR system for years to come.

Courtesy Air and Space magazine,
Smithsonian Institution

LOW LEVEL time control–the 1.5 method

Captain Randall R. SCHMIDT
452 FTS
Mather AFB, CA

Ask experienced navigators for their method of low level time control and you may get as many different methods as the number of people questioned. Most will reply: "If you're behind, push the throttles up; if you're ahead, pull them back." However, if you're on a check ride or participating in a low level competition, you might favor a more specific correction method. Such a method would be even more vital in a combat scenerio where split second timing over intermediate checkpoints is critical.

How would you like to have a timing control method accurate to within seconds that you can compute mentally while airborne? Your correction adjustment can be maintained for an entire low level leg rather than you're having to correct again part way through a leg. By

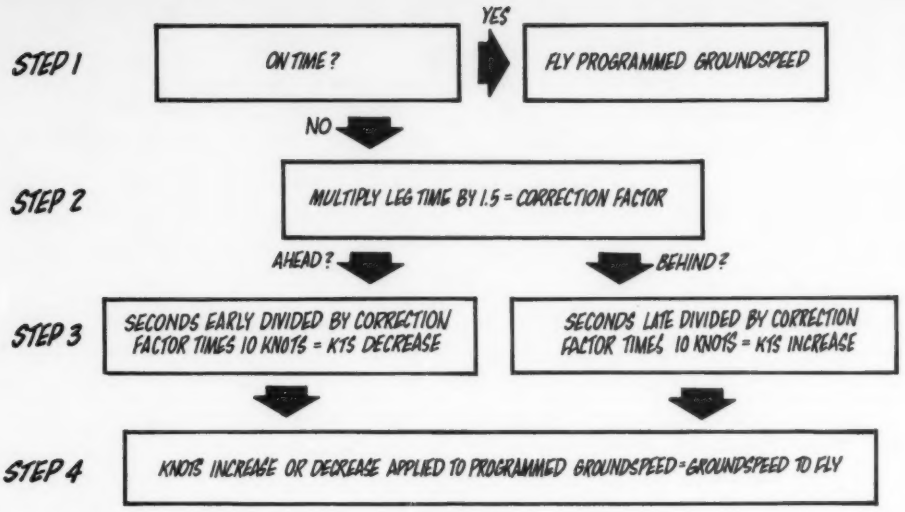

STEP 1
ON TIME?
YES
FLY PROGRAMMED GROUNDSPEED
NO
STEP 2
MULTIPLY LEG TIME BY 1.5 = CORRECTION FACTOR
AHEAD?
BEHIND?
STEP 3
SECONDS EARLY DIVIDED BY CORRECTION FACTOR TIMES 10 KNOTS = KTS DECREASE
SECONDS LATE DIVIDED BY CORRECTION FACTOR TIMES 10 KNOTS = KTS INCREASE
STEP 4
KNOTS INCREASE OR DECREASE APPLIED TO PROGRAMMED GROUNDSPEED = GROUNDSPEED TO FLY

Figure 1

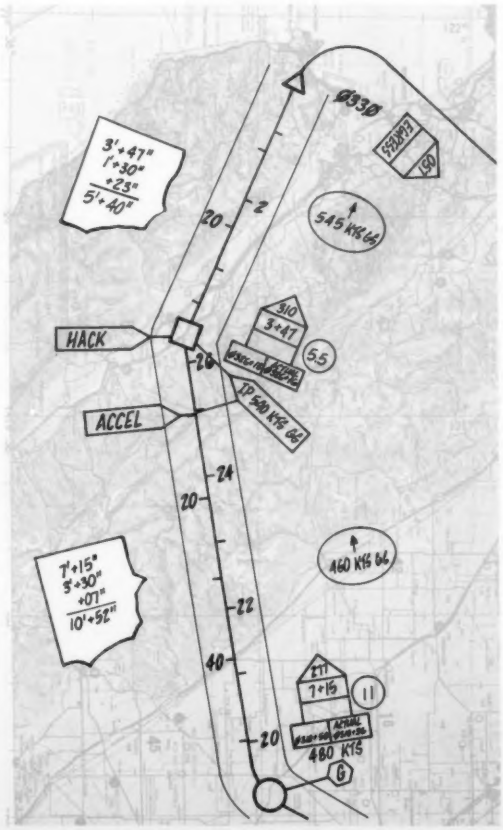
accurately coordinating airspeed, you allow yourself more time to cross-check altitude and heading. Also, you have additional time to counter threats and check six.

The best way to determine your airspeed and estimated time en route (ETE) for any given leg distance is to spin solutions for different speeds on the trusty MB-4 computer. With en route times for 10-knot speed increments, one would simply fly the required airspeed to arrive at successive checkpoints on time. However, such calculations require excessive preflight work and, also, 10 knot increments may not produce the desired accuracy. A better method would be a quick mental formula that can be employed in flight.

My solution to the problem is the "1.5 method." If a navigator takes time to compute leg ETEs at different groundspeeds, a by-product is an approximate correction factor for each 10 knots of increase or decrease. For example, a 73 nm leg flown at 420 kts groundspeed takes 10 min and 26 sec. Each 10 kts change in speed produces approximately 15 seconds of time correction. To compute the correction factor, simply multiply the en route leg time by 1.5. Multiplying 10 min 26 sec (10.4) by 1.5 yields a correction factor of 15.6 seconds. By dividing the number of seconds ahead or behind by 15.6, we arrive at a corrected groundspeed to be maintained during the entire 73 nm leg. Suppose we are 31 seconds early starting the leg. Dividing 31 by 15.6, we find that a 2-times-10 knot decrease (20 kts), held for the leg's duration, will lose the 31 seconds and put us back on schedule. Fig 1 shows a simple illustration of how this procedure works.

Here's a sample problem to further illustrate the method. Referring to Fig 2, assume that you arrive 22 seconds early at point Gulf. The next leg, into the IP, is 7 min 15 sec at 480 kts programmed groundspeed. Simply add 3 min 37 sec to 7 min 15 sec (another way to multiply a number by 1.5 is to add half of the number to itself) to find an 11 sec correction factor. Dividing this factor into 22 sec early yields a 20 kt groundspeed decrease. Therefore, if we pull the throttles back to 460 kts groundspeed at point Gulf, we will be on time at the IP.

Figure 2



As already mentioned, this method can be employed at each checkpoint and maintained until the next. One suggestion for using this method is to compute the "correction factor" for each leg during preflight planning. This can be done on the way to the airplane and recorded in the course arrow box for each leg.

The 1.5 method is very beneficial since the timing ticks used for mental DR on a low level chart are accurate only if you are on time. Therefore, arriving on time at each checkpoint significantly aids your radar or visual navigation.

Next time you fly low level and find yourself off time, try the 1.5 method. You'll see how easy it is to be on course and on time.

A graduate of Park College in Missouri, Capt Schmidt entered the Air Force via OTS. In 1979, he completed UNT and was then assigned to the F-4 in Korea, followed by Seymour Johnson AFB. Capt Schmidt is an instructor with the 452 FTS.

I AM THE NAVIGATOR

First Lieutenant Robert C. Bruno
61 TAS
Little Rock AFB, AR

Around the World

Captain Scott F. MERROW
38 SRS
Offutt AFB, NE

Around the world in four minutes! Sound amazing? Well, believe it or not, it's true. I know—I was there. And it wasn't in the space shuttle, or an SR-71, or any other aircraft you'd normally associate with high-speed travel. We did it in an RC-135, one of SAC's long-range strategic reconnaissance aircraft. If you're wondering how we did it, read on, because circling the world in four minutes was only one highlight of many experienced during an interesting and challenging mission. The flight was especially challenging for the nav team (the RC-135 has two navigators). During the mission, we employed several relatively obscure techniques from the navigator's "bible," AFM 51-40.

Our crew was TDY in England when we were tasked, unexpectedly, to ferry an aircraft to Alaska. We shared the aircraft with a Raven crew (electronic warfare officers). We'd been in England about a week, enjoying unusually nice weather. None of us was anxious to leave, especially for Alaska! Of course, we had no choice so we decided to make the flight as enjoyable as possible. We planned our mission straight up the prime meridian to the north pole, and then due south (I know, I know—south is the only possible initial direction from the north pole!) to recover approximately ten hours later in Alaska.

The in-flight portion of the mission was unusual from the beginning. Shortly after takeoff, and just before our scheduled air refueling, during a routine sextant check we discovered that our sextant port was completely frozen shut! We couldn't continue without the sextant because we planned to spend over eight hours in grid. We certainly needed to keep tabs on our heading references.

The RC-135 has a very accurate inertial navigation system but, like all machines and most people, it has its good and bad days. Even when the system is right on the money, an occasional celestial position and heading check will certainly bolster your confidence—especially when flying over water and out of radar range. So, we started trying to thaw out the sextant port.

First we tried the aircraft's portable signal lamp. Ever since I've been flying 135s, the "old heads" have told me that the signal lamp (usually called the Aldis lamp) will generate enough heat to thaw out a frozen sextant port. Don't believe it! It doesn't work. We then tried holding cups of hot water and coffee near the port, hoping the steam would thaw it—that didn't work either. After these attempts failed, we actually began to think about aborting the mission. Then, one of the Ravens offered an idea. He had an electric hair dryer in his suitcase. We plugged in the hair dryer and aimed it at the sextant port. Sure enough, in a few minutes the port was completely thawed and usable.

With that crisis over, we were ready to press on. We completed the air refueling and headed for the north pole. The nav team still had little time to relax. Our real work was just beginning. During the next several hours we'd be putting our training and experience to the test. Navigation in polar areas can be a real challenge. It exposes a navigator to things previously encountered only as "war stories" or lessons from a textbook—things ranging from difficult polar navigation procedures to unusual techniques that many navigators don't experience during an entire career.

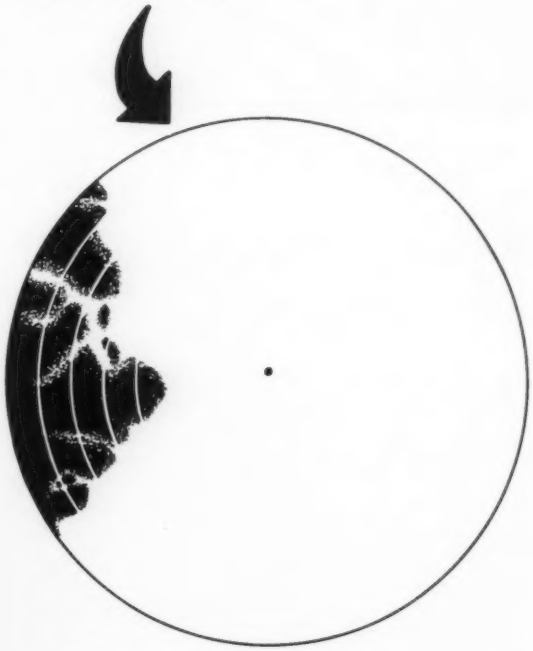
Our polar segment began routinely. We entered grid at 68 degrees north. Actually, we entered a semigrid mode. Let me explain. By design, grid north and true north are the same on the prime meridian. With a convergence angle of zero, our true heading and grid heading would be the same all the way to the pole. This really simplified our navigation, but we still had to use grid procedures. The two problems in polar areas that make grid navigation necessary are the converging meridians of longitude and the unreliability of magnetic compasses (primarily due to unmeasurable magnetic variation). These problems are as critical along the prime meridian as in any other area close to the poles. So we entered grid, but we were flying along the only track in the world where grid and true references coincide.

in Four Minutes

The coincidence of grid and true north vastly simplified another of our chores—chart transition. At 75 degrees north, we'd reached the limit of our first chart. The next one was a polar projection. Of course, this meant a change in convergence factor from .785 to 1:1. Normally, the change requires using a transverse mercator correction graph (remember those?). However, on the prime meridian, regardless of the convergence factor, the convergence angle is zero and the correction from the graph is also zero. Our grid direction on the first chart was the same as grid direction on the second. So, our chart transition couldn't have been simpler. We kept our correction graphs handy—we'd still need them on the southbound leg of our trip, over on the other side of the world.

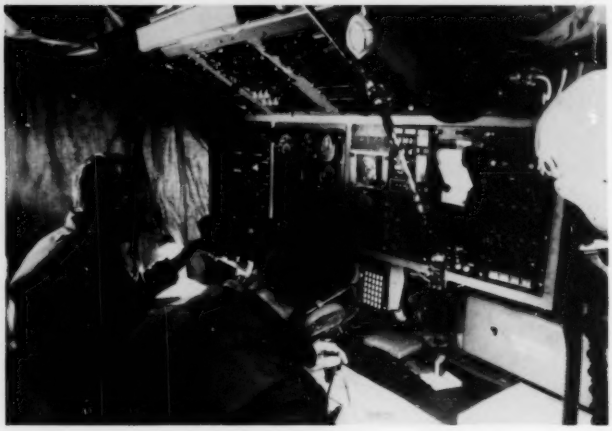
In the meantime, we experienced a couple more out-of-the-ordinary phenomena that make navigation so interesting. Not long after chart transition, at approximately 82 degrees north, we'd planned to get our last outbound radar fix using a craggy-looking point of land on the northeast end of Greenland as the target. We expected to see a radar picture something like this:

Instead, we saw this:



There it was—the dreaded "arctic reversal!" The smooth snow covering the land presented a negative radar return, while the roughness of the arctic sea ice created positive images. Fixing from such returns can be tricky, but the biggest problem is psychological. It's tough to teach an old dog new tricks, and that applies to "crew dogs" too. After a few thousand hours of seeing land as a positive radar return and water as

negative, arctic reversal takes some getting used to. Also, a coastline is very poorly defined under such conditions. Still, with good DR and some careful radarscope interpretation (remember, chart-to-scope), we managed to distinguish mountain peaks that were usable targets. We took our fix. The position looked good and we were on our way again.



We were approaching the really high latitudes now. Nearing 88 degrees north, Major Olivo, my nav partner, remembered another seldom-used technique from AFM 51-40—use of the pole as an assumed position (only an ex-UNT instructor would remember THAT one!). It's a very good technique. We used it twice, on each side of the pole, and it saved us a lot of work. All you need is an Air Almanac. The GHA of the body becomes the computed azimuth (Zn) and the declination of the body becomes the computed altitude (Hc). For stars, of course, you'll have to add the SHA of the star to the GHA of Aries (star's SHAs and declinations are found on the first page following the daily pages). To facilitate plotting, convert the Zn to grid by adding or subtracting 180 degrees. Also, don't forget to correct for refraction and Coriolis; Precession and Nutation correction is not required. If you shoot early or late, a correction for motion of the observer is still necessary, but not for motion of the body. Using this technique, you can finish a computation in less than a minute. Unfortunately, you probably won't be able to use the technique often—it's only appropriate within two degrees of the pole.

Shortly after plotting our first celestial position, we reached the highlight of the mission—passage over the north pole! Approaching the pole, several crew members had their cameras ready for pictures of two seldom observed sights—the actual geographic north pole and our inertial present position display reading 90 degrees north. With seconds remaining, I kept my finger poised, waiting to press the HOLD button at just the right instant and freeze the display. Three seconds, two, one, HOLD—and there it was, 90 degrees north! Everyone took pictures of the INS display and we began a left turn. As we turned, the photographers pointed their cameras earthward for pictures of the polar ice cap. It was an extremely clear day at the pole, so they got some good pictures. However, there's not much to see—just ice (nope, no big red-and-white striped barber pole, and not a sign of Santa Claus!). Still, it is the north pole and a picture of it (even from 30,000 feet) is something to show one's grandchildren some day.

After all the pictures were taken, rather than roll out on a heading for Alaska, we continued our left turn. We turned through 360 degrees, completing our circle of the north pole. And that's how it happened—around the world in four minutes! In four minutes we crossed every meridian of longitude and passed through all 24 time zones—just for the fun of it! I'll bet very few people can say they've circled the world in four minutes! (Where are the Guinness records people when you really need them?)

After our 360, we headed due south—the particular "due south" that would take us to Alaska. We still had a long way to go, but the rest of the mission was routine—even anticlimactic. We got our chance to do some real grid navigation (with genuine convergence angles) and we found an opportunity to use our transverse mercator correction graphs. We even saw more arctic

reversal as we approached the north slope of Alaska.

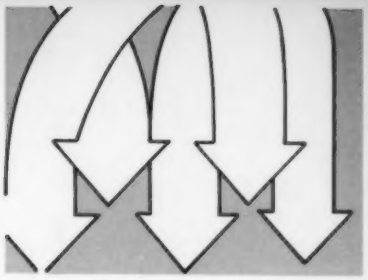
After approximately ten hours in the air, we landed—half a world away from our point of departure. Stepping off the airplane, into the cool Alaskan air, we shared the pride of fulfilling our mission while logging a unique sortie—a cross-country circumpolar navigation.

Capt Merrow graduated from St Bonaventure University in 1973 with a degree in Mathematics. Commissioned through OTS in 1975, he next completed UNT and CCTS. He next served at Offutt AFB in the RC-135. Capt Merrow now is a Stan/Eval flight examiner.

NAV, PILOT: WHERE ARE WE?
STANDBY ONE---
ACCORDING TO MY SOPHISTICATED EQUIPMENT AND SUPERLATIVE PLOTTING, I CAN FIRMLY STATE THAT WE'RE DIRECTLY SOUTH OF THE NORTH POLE!

Humor Contributed by
Thomas J. MELTON
Det 3, 3314 MES
Mather AFB, CA

BACK TO BASICS:



Positioning by Polaris

Captain Gregg L. BROWN
337 BMS
Dyess AFB, TX

When considering night celestial navigation, Polaris is often the first star that comes to mind. The pole star offers navigators in the northern hemisphere a number of options for celestial fixing. Polaris is a unique star due to the close proximity of its subpoint to the earth's north pole—the star is about one degree offset from the earth's axis. This proximity results in very little change in the apparent position of Polaris throughout the night-viewing period. For the navigator, Polaris offers several advantages and disadvantages which vary according to your methods of sight reduction and observation.

I'll address Polaris fixing by three different methods. The first is the basic method of manual observation and manual sight reduction. The second method combines manual observation with sight reduction by hand-held calculator or computer. The last method employs an astrotracker for automatic sighting and sight reduction.

METHOD ONE: MANUAL OBSERVATION AND SIGHT REDUCTION.

Polaris fixing by manual observation and sight reduction still is probably the most popular method. Procedures are quite simple. First, preset the sextant altitude to the observer's latitude and set the azimuth counter to zero. Next align the sextant mount ring to the aircraft heading and obtain the Ho for reduction. If shooting a star other than Polaris, you might first need precomputed altitude and azimuth values to find the star.

Just as the sighting of Polaris is unique, sight reduction is also unique for the north star. Rather than plot a Polaris line of position (LOP) by the standard intercept method, a latitude-by-Polaris LOP is derived. Most navigators have used this very easy option. As previously stated, precomputation is not necessary to obtain the Ho for reduction. Likewise, a full "precomp" is not necessary to determine your latitude by Polaris. The navigator simply corrects the sighted Ho for refraction and "Q." The Q-correction compensates for the one degree angle between the earth's northern axis and Polaris' path around it. Once the corrections for refraction and Q have been applied to the Ho, the value can be plotted. Before plotting, corrections for Coriolis/Rhumbline, along with Precession and Nutation, must be computed. To draw the LOP, first plot the corrected Ho as a point of latitude near the DR. Next, move the point for Precession and Nutation (P&N). The P&N correction table is in the back of the red H.O. 249 Volume. After adjusting for P&N, you must further correct the point for Coriolis/Rhumbline. Through this corrected point, you can now draw the line of equal latitude—your latitude-by-Polaris LOP.

It's interesting to note that, except for obtaining sighting corrections for the reduction process, the H.O. 249 volumes are not required for resolving this LOP. In fact, the declination limits of the white and blue volumes restrict their use in resolving Polaris by the common intercept method. This leaves only the latitude-by-Polaris method for use with manual observation and manual reduction.

METHOD TWO: MANUAL OBSERVATION AND CALCULATOR SIGHT REDUCTION.

With the increasing capability and decreasing cost of portable calculators and computers, these devices are seen more and more in the cockpit. They are welcomed by navigators who find them ideally suited to preflight and in-flight calculations. Celestial computations are another job where these digital wonders most appeal to navigators. Calculator computations for Polaris are no more difficult than those for other stars. However, there can be some confusion about use of the Q-correction.

The Q-correction, as previously mentioned, is used to correct a Polaris sighting to true north, for plotting the latitude-by-Polaris LOP. During manual reduction, this allows convenient use of Polaris without the availability of an accurate precomputed Hc from the H.O. 249 Volumes. It is, then, a shortcut method of computing Polaris manually.

Calculators aid celestial computations by employing a mathematical formula to resolve the Hc—the same formula used to produce the Sight Reduction Tables. The main difference is that calculators compute the Hc and Zn separately, while the H.O. 249 Volumes merely list whole numbers of declination, latitude, and LHA. Since the calculator method is for one specific solution, versus complete tables of solutions, the restriction of rounded-off entering arguments doesn't apply. Actual dead reckoning coordinates may be used for both plotting and computing, instead of "assumed" or whole latitude coordinates. Likewise, computers eliminate our restriction to only those stars in the red volume or to declinations from the white and blue volumes. Therefore, with the computer, we can figure the altitude and true bearing of any celestial body for which we can determine a GHA and declination.

To determine the GHA and declination of Polaris, you first extract its Sideral Hour Angle (SHA) and declination (Dec) from the back of the Air Almanac's Q-correction table. This declination can be used directly. The SHA must be either mechanically combined with the extracted GHA or entered with the GHA of Aries into the calculator, depending upon the model used, to determine the GHA of Polaris. This GHA of the body is then internally compared to the entered longitude to develop the LHA. All values are then plugged into the formula to produce an Hc and Zn.

Once the Hc and Zn have been computed and the assumed position adjusted for Coriolis and P&N, the LOP is plotted normally. Do not assume that this LOP will be an exact line of latitude, as with the manual method. The LOP will only be an exact line of latitude on the two times each day when the observer, the north pole, and Polaris share the same great circle. Still, the LOP will closely approximate a line of latitude, differing by a maximum of only one degree at moderate to lower latitudes of observation. Computer sight reduction requires correction for refraction, Coriolis/Rhumbline, and P&N. The Q-correction is not necessary for developing this intercept-by-Polaris LOP.

METHOD THREE: AUTOMATIC SIGHTING AND AUTOMATIC SIGHT REDUCTION.

This information will aid those navigators fortunate enough to have an astrotracker available. As a representative model, the MD-1 astrotracker, found on the B-52, will be used for this discussion. The astrotracker is operated by first presetting the GHA of Aries, which is then driven at the sidereal rate. Next, the SHA and Dec of Polaris is normally set into the first of three available star packages. An assumed position of latitude or longitude is required for the internal calculation of LHA, thereby allowing calculation

CORRECTIONS	METHOD ONE	METHOD TWO	METHOD THREE
CORIOLIS/RHUMBLINE	YES	YES	IF OTHER THAN 450 KTS GS
PRECESSION & NUTATION	YES*	YES*	YES
REFRACTION	YES	YES	YES
Q	YES	NO	NO

*P & N NEED NOT BE APPLIED IF "Q" IS TAKEN FROM A CURRENT AIR ALMANAC

of the Hc and Zn of Polaris for that specific position. This assumed position can be automatically fed into the astrotracker from the aircraft's navigation computer or manually set by the operator.

Entering arguments for the astrotracker are the same as those for the calculator method. In fact, the only significant difference between celestial computing with the two devices is that the astrotracker receives automatic inputs while the calculator requires manual operation for each separate sight reduction. Celestial information available from the astrotracker, for resolving the LOP, includes the assumed DR coordinates, which can be read at the mid-time of any two-minute observation period; the true azimuth (Zn), which is also read at the mid-time; and the altitude/intercept, which is averaged over the entire two-minute period and used for plotting. Once this information is obtained, the navigator plots the average intercept from the assumed position, adjusted for P&N and Coriolis errors. The astrotracker automatically compensates for Coriolis for a groundspeed of 450 kts. If the groundspeed differs significantly from 450 kts, the Coriolis correction must be adjusted to 450 kts GS. Once again, no Q-correction applies with electronic or automatic sight reduction machines, whether a calculator, computer, or astrotracker. At lower latitudes, a refraction correction must be applied to the computed altitude as with all observations, through the earth's atmosphere, of low-altitude bodies.

Hopefully, this brief review of procedures for fixing with Polaris will leave you in good stead for your next night navigation leg. When all else fails, it's nice to fall back on the basics.

Capt Brown graduated from Embry-Riddle Aeronautical University in 1972 with a degree in Aeronautical Science. After OTS, he completed UNT and NBT in 1974. He then served in the B-52H at Grand Forks AFB before instructor duty at Mather AFB. Capt Brown now is assigned to Dyess AFB.

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